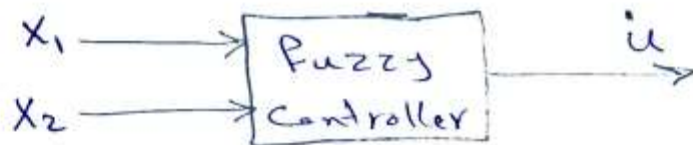


Lec 5 - Fuzzy

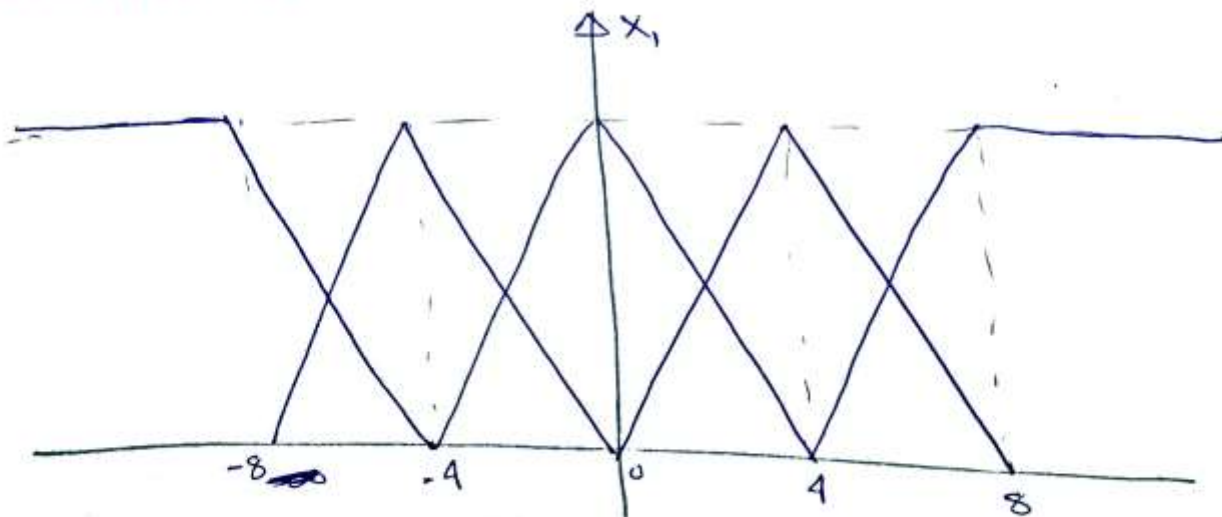
□ Draw a suitable MFS to represent the following inputs ^{and output} of a fuzzy controller



For i/p $X_1 \Rightarrow$ use the no. of fuzzy sets = 5
and universe of discourse from -8 to 8

For i/p $X_2 \Rightarrow$ use no. of sets = 7 and universe
of discourse from -3 to 3

For o/p $u \Rightarrow$ use no. of fuzzy sets = 5 and
universe of discourse from -10 to 10.



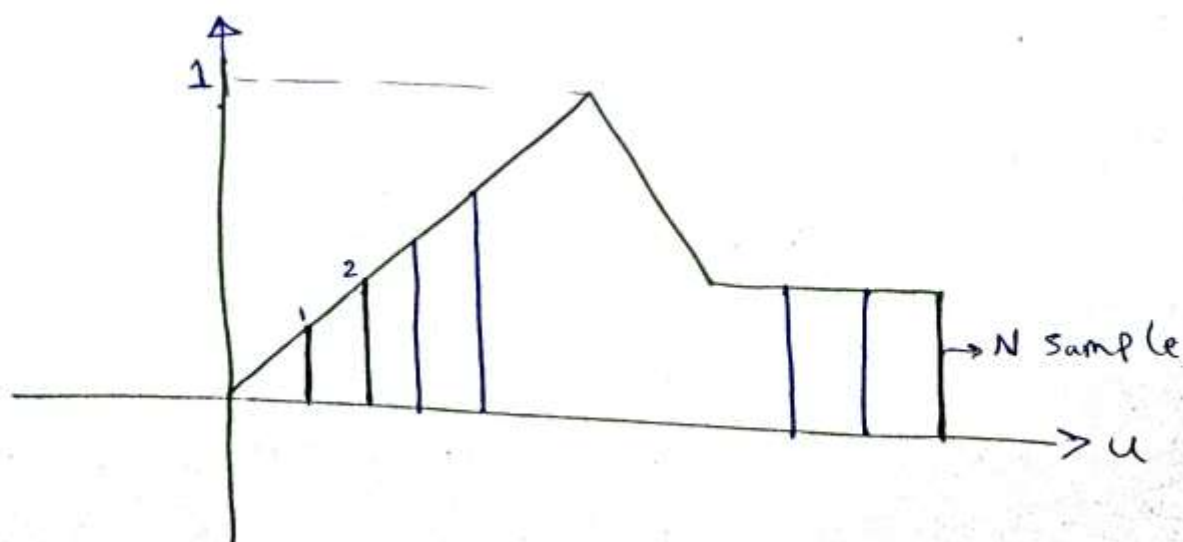
$$U^{\text{crisp}} = \frac{\int_{I_1}^{I_2} \mu(u) u du + \int_{I_2}^{I_3} \mu(u) u du + \int_{I_3}^{I_4} \mu(u) u du}{\int_{I_1}^{I_2} \mu(u) du + \int_{I_2}^{I_3} \mu(u) du + \int_{I_3}^{I_4} \mu(u) du}$$

↳ this method is considered the most accurate method.

⇒ the discrete form of CoG method

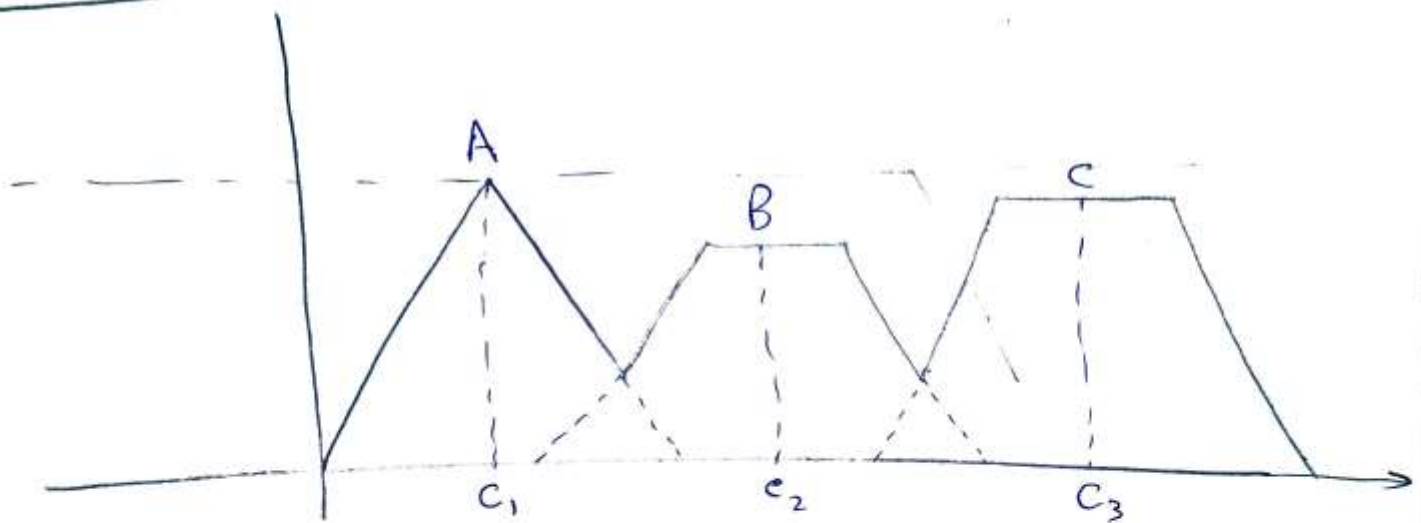
$$U^{\text{crisp}} = \frac{\sum_{i=1}^N \mu(u_i) \cdot u_i}{\sum_{i=1}^N \mu(u_i)}$$

Ex-1



له القيمة الـ (discrete) ممكنة تذكره من طريقة ادى
للتكامل هنزود عدد الـ (Samples).

[2] Max-Mean Membership method :-



$$\mu_{crisp} = \frac{c_1 + c_2 + c_3}{3}$$

له بيوت للقيم المتأخرة لا (Maximum) بتاع
كل (Set) ويحذف ويقسم على الـ
(average)

For discrete

$$\mu_{crisp} = \frac{\sum_{k=1}^N c_k}{N}$$

where: c_k is the corresponding value to
peaks of o/p fuzzy set

[3] weighted Average method:-

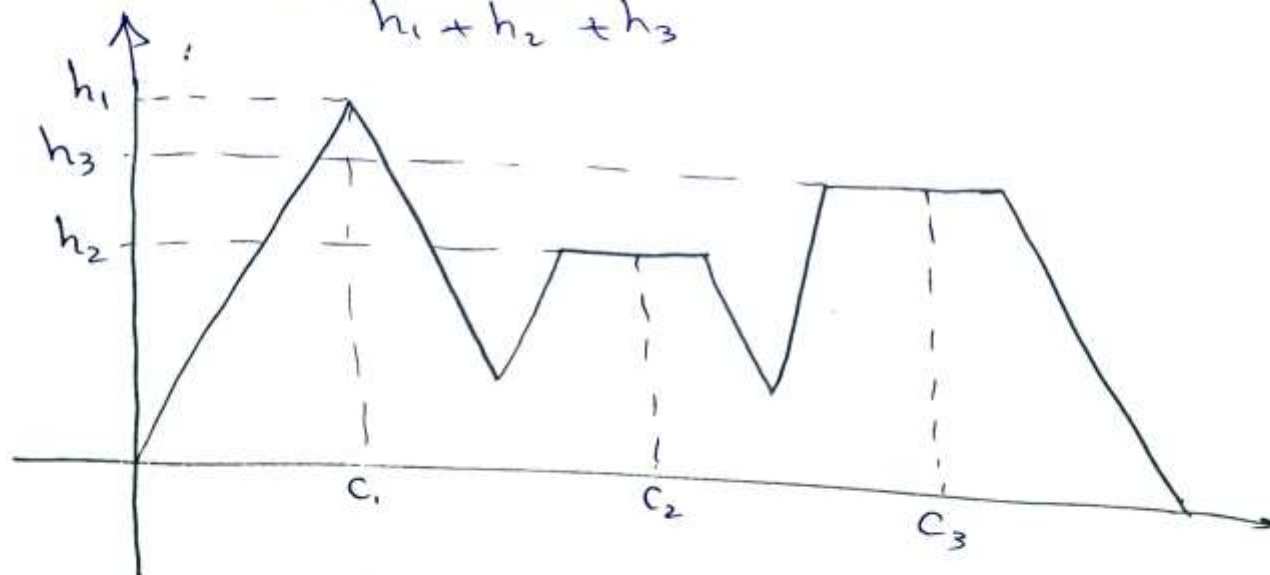
~~[1] crisp & fuzzy u^{crisp} is calculated as~~

$$u^{crisp} = \frac{\sum_{i=1}^N \mu(u_i) \cdot u_i}{\sum_{i=1}^N \mu(u_i)}$$

Where u_i is the symmetric point to the fuzzy set of form.

in Previous Graph

$$u^{crisp} = \frac{c_1 h_1 + c_2 h_2 + c_3 h_3}{h_1 + h_2 + h_3}$$

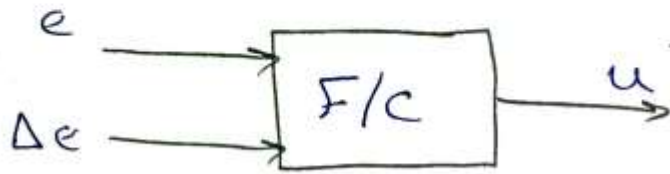


symmetric of (fuzzy) is calculated as

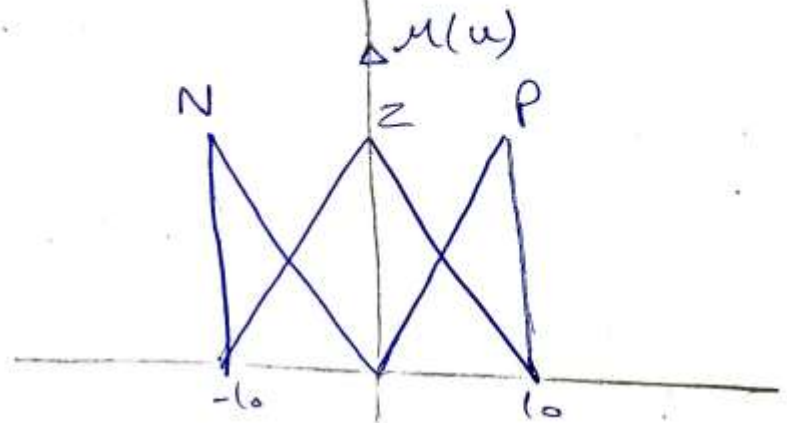
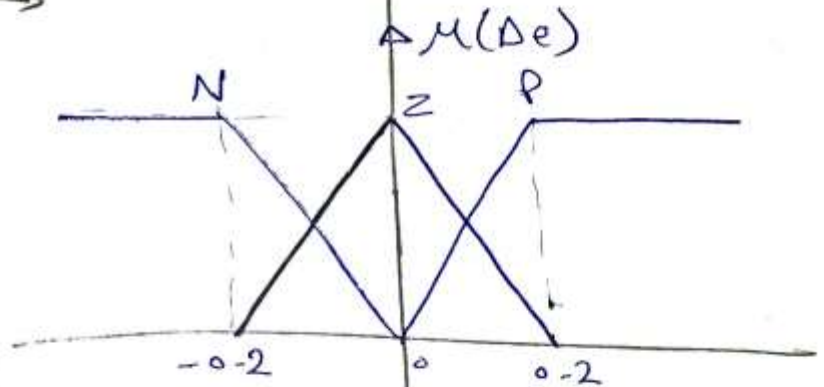
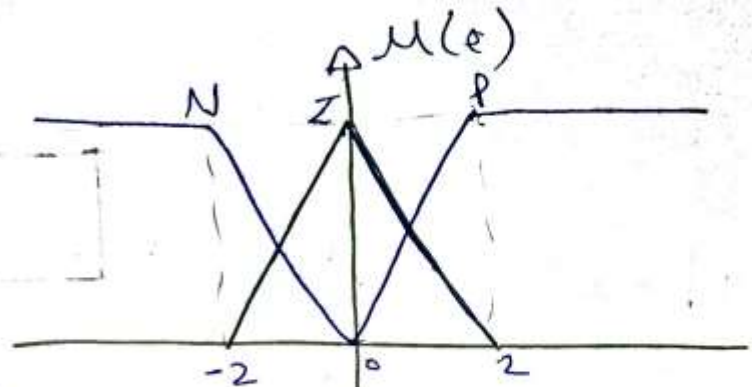
as follows

[5]

Ex



$\begin{matrix} e \\ \Delta u \end{matrix}$	N	Z	P
N	P	P	Z
Z	P	Z	N
P	Z	N	N



Find the crisp o/p in following case

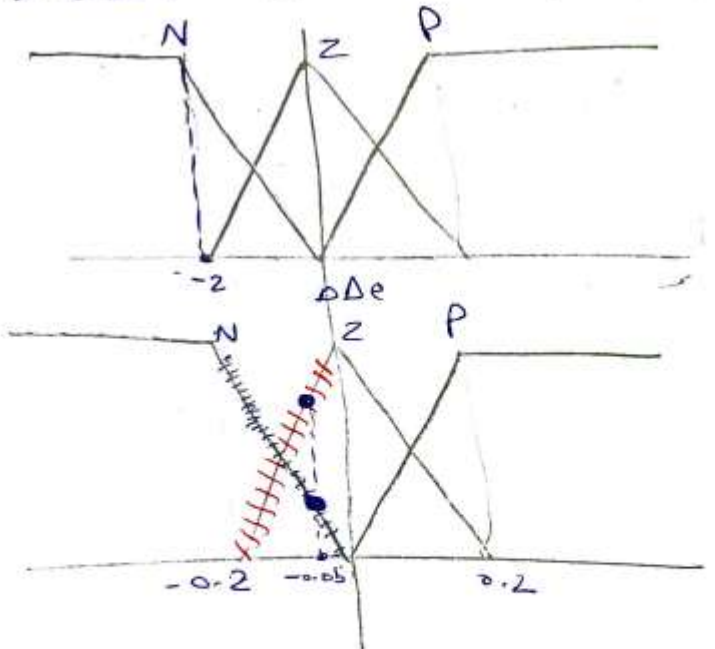
- 1) $e = -2$ & $\Delta e = -0.05$
- 2) $e = 1.5$ & $\Delta e = -0.15$
- 3) $e = 2$ & $\Delta e = 0.2$
- 4) $e = 1$ & $\Delta e = 0.1$

Solution →

□ $e = -2$ & $\Delta e = -0.05$

1) Fuzzification

$e = -2 \Rightarrow N$ with $\mu = 1$ "error is negative"



$\Delta e = -0.05$

→ N with $\mu = \text{value} = 0.25$

→ Z with $\mu = 0.75$

له فنحسب معادلة الخط المتكلم بالانجليزية ()

$$\frac{y - 0}{x - 0} = \frac{1}{-0.2} \Rightarrow y = -5x \quad \begin{matrix} \downarrow \\ \mu(\Delta e) \end{matrix} \quad \begin{matrix} \downarrow \\ \Delta e \end{matrix}$$

$$\mu = -5 \Delta e$$

Put $\Delta e = -0.05 \Rightarrow \mu = 0.25$

ومعادلة الخط الآخر فنحسبها ونعوض فيها ب -0.05

$$\mu = 0.75$$

2] The Fired rules (which rules are on)

له منشور الناتج في ال (Fuzzification) ونسب
عالبول وناخذ القواعد التي معانا .

R_1 : if e is N & Δe is N

then u is P

Premised
terms

$e \backslash \Delta e$	N	
N	P	
Z	P	

R_2 : if e is N & Δe is Z

then u is P .

3] The strength of fired rules:

له مدى صحة وقوة ال (rules) التي انا جيت .

$$\mu_{P_1} = \min \{ \mu_N(e = -2), \mu_N(\Delta e = -0.05) \}$$

Premise

$$= \min \{ 1, 0.25 \} = 0.25$$

$$\mu_{P_2} = \min \{ \mu_N(e = -2), \mu_Z(\Delta e = -0.05) \}$$

$$= \min \{ 1, 0.75 \} = 0.75$$

الخطوة السابقة مفيدة على ما أجي أطلبه ال (actions)
 i.e. كرف ال (strength) بتاع ال (rules) ال .

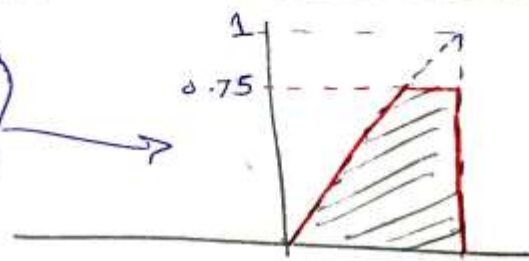
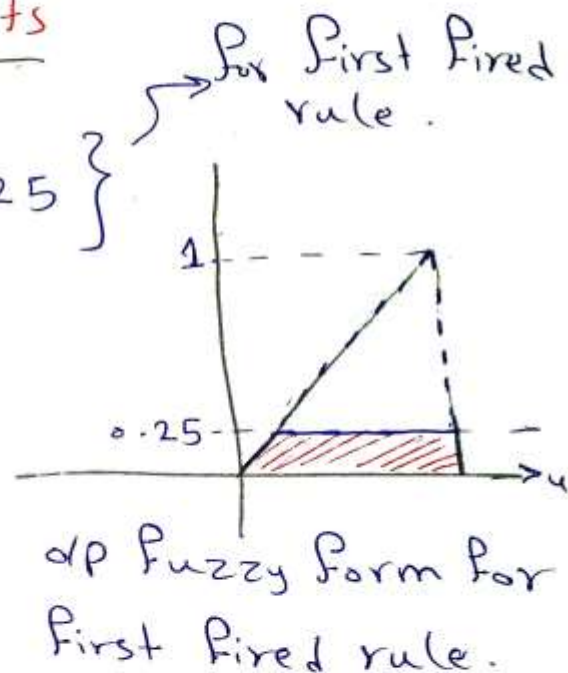
4] The Forms of o/p Fuzzy sets

$$\mu_{p_1}(u) = \min \{ \mu_p(u), 0.25 \}$$

$$\mu_{p_2}(u) = \min \{ \mu_p(u), 0.75 \}$$

↳ for second fired rule

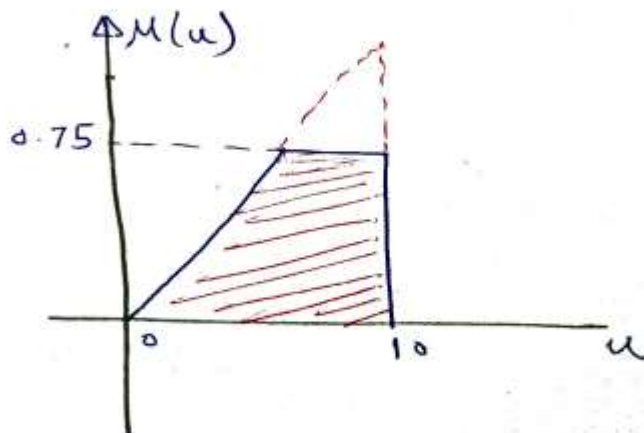
o/p Fuzzy Form for second fired rule



"OR operation" ← (Aggregation) لـ كلف التجميع

5]

overall o/p Fuzzy Form



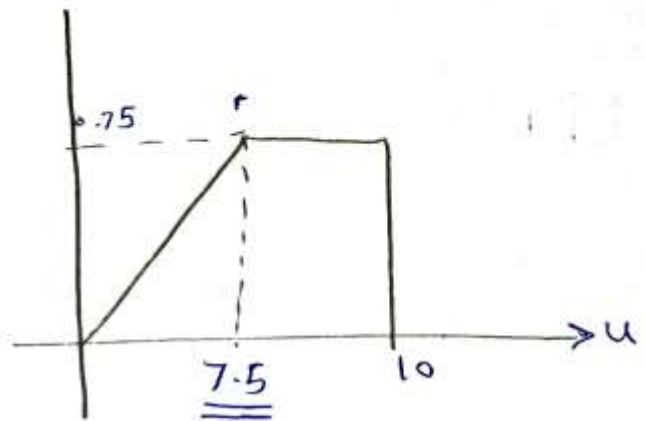
Defuzzification using (CoG)

→ يجب معرفة الخط الكاثل

$$\mu = 0.1 \text{ u}$$

$$0.75 = 0.1 \text{ u}$$

$$\hookrightarrow u = 7.5$$



$$\text{crisp } u = \frac{\int_0^{7.5} \mu(u) \cdot u \, du + \int_{7.5}^{10} \mu(u) \cdot u \, du}{\int_0^{7.5} \mu(u) \, du + \int_{7.5}^{10} \mu(u) \, du} = \frac{I_1}{I_2}$$

$$I_1 = \int_0^{7.5} (0.1u)u \, du + \int_{7.5}^{10} 0.75u \, du$$

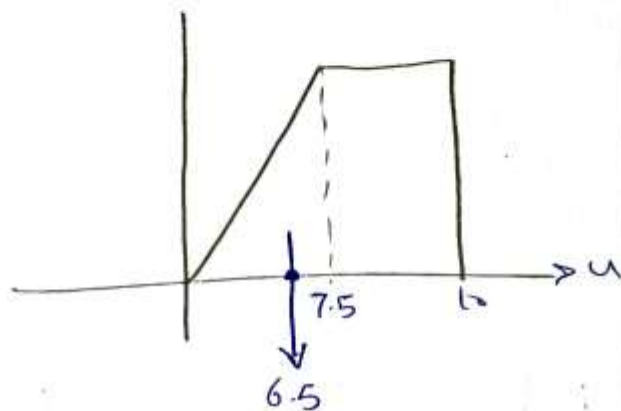
$$= 0.1 \frac{u^3}{3} \Big|_0^{7.5} + \frac{0.75u^2}{2} \Big|_{7.5}^{10}$$

$$I_1 = 30.468$$

$$I_2 = \int_0^{7.5} 0.1u \, du + \int_{7.5}^{10} 0.75 \, du$$

$$I_2 = 0.1 \frac{u^2}{2} \Big|_0^{7.5} + 0.75 u \Big|_{7.5}^{10}$$

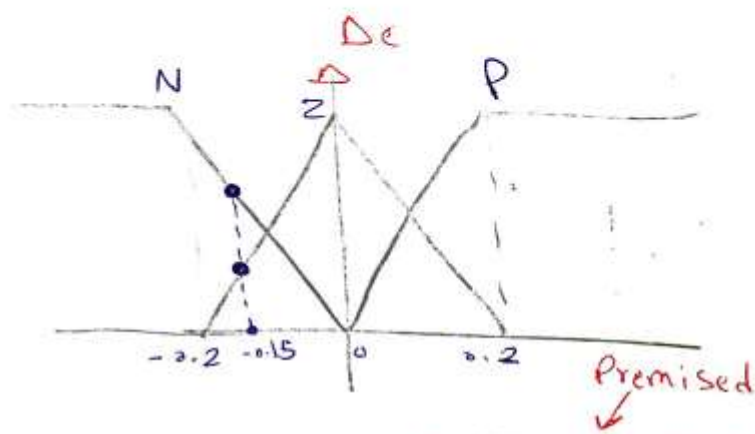
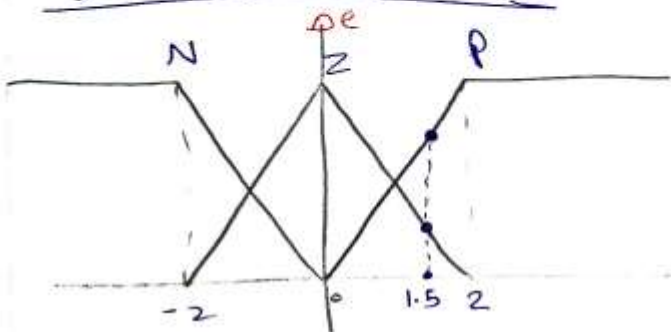
$$I_2 = 4.6875$$



$$\text{crisp } u \rightarrow \frac{I_1}{I_2} = 6.5$$

$$\boxed{2} \quad e = 1.5 \quad \& \quad \Delta e = -0.15$$

1) Fuzzification



$e = 1.5 \rightarrow \begin{cases} Z \text{ with } \mu = 0.25 \Rightarrow e \text{ is } Z \\ P \text{ with } \mu = 0.75 \Rightarrow e \text{ is } P \end{cases}$

$\Delta e = -0.15 \rightarrow \begin{cases} N \text{ with } \mu = 0.75 \Rightarrow \Delta e \text{ is } N \\ Z \text{ with } \mu = 0.25 \Rightarrow \Delta e \text{ is } Z \end{cases}$

له قيم ال μ هيتجيب لستنتاجه من الرسم.

2) Fired rules

$\Delta e \backslash e$	N	Z	P
N		P	Z
Z		Z	N

R₁: if e is ^{0.25}z & Δe is ^{0.75}N $\Rightarrow u$ is P

R₂: if e is ^{0.75}P & Δe is ^{0.75}N $\Rightarrow u$ is Z

R₃: if e is ^{0.25}Z & Δe is ^{0.25}Z $\Rightarrow u$ is Z

R₄: if e is ^{0.75}P & Δe is ^{0.25}Z $\Rightarrow u$ is N

3) strength of Fired rules

$$\mu_{P_1} = \min \{0.25, 0.75\} = 0.25$$

$$\mu_{P_2} = \min \{0.75, 0.75\} = 0.75$$

$$\mu_{P_3} = \min \{0.25, 0.25\} = 0.25$$

$$\mu_{P_4} = \min \{0.75, 0.25\} = 0.25$$

4] Forms of old Fuzzy sets

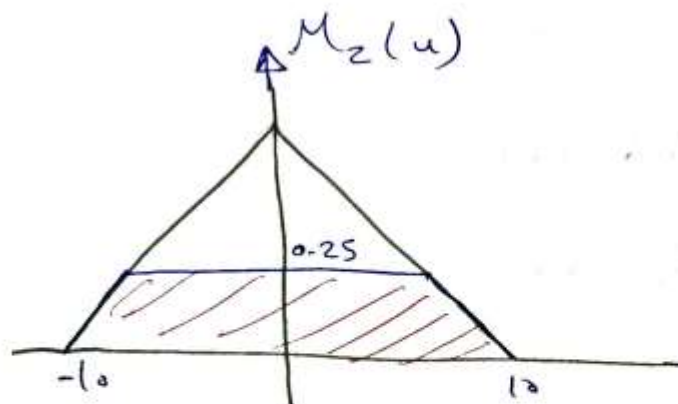
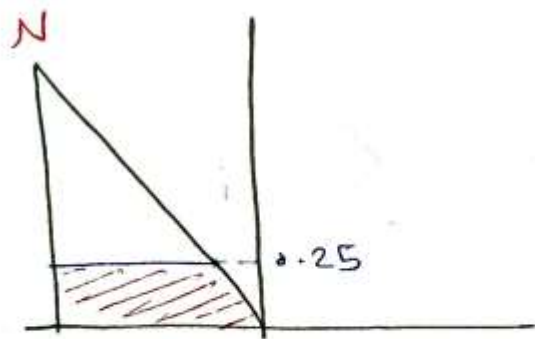
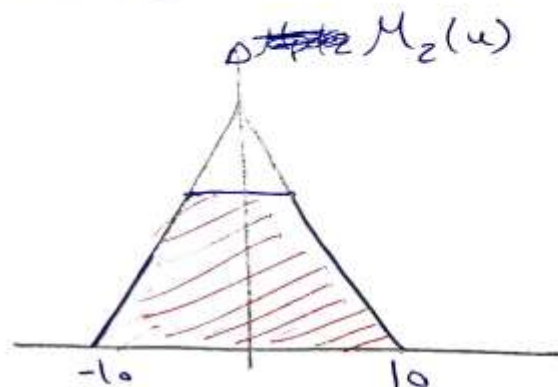
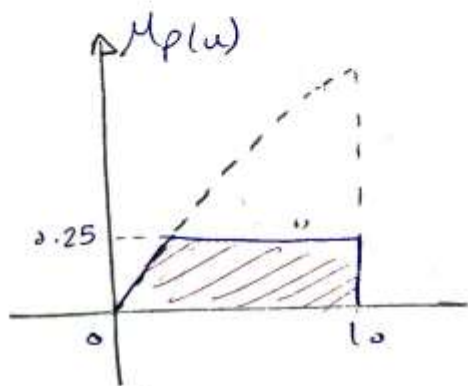
For the Fired rule R_1 :

$$\mu_p(u) = \min\{\mu_p(u), 0.25\} \rightarrow \text{For } R_1$$

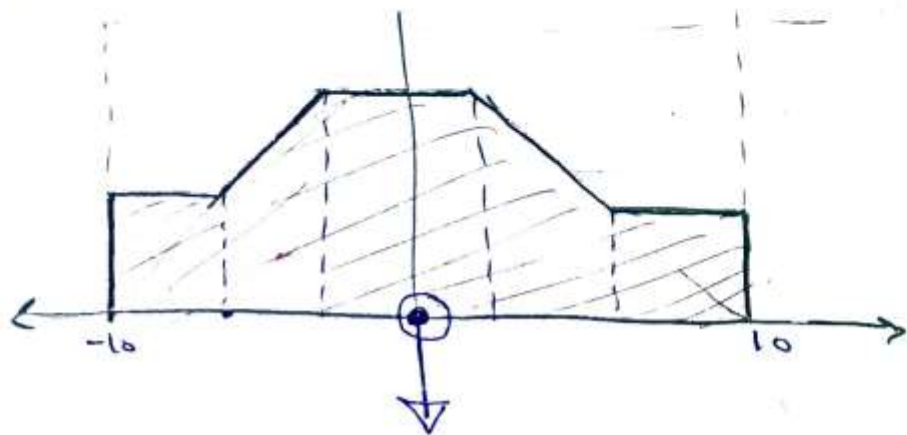
$$\mu_z(u) = \min\{\mu_z(u), 0.75\} \rightarrow \text{For } R_2$$

$$\mu_z(u) = \min\{\mu_z(u), 0.25\} \rightarrow \text{For } R_3$$

$$\mu_N(u) = \min\{\mu_N(u), 0.25\} \rightarrow \text{For } R_4$$



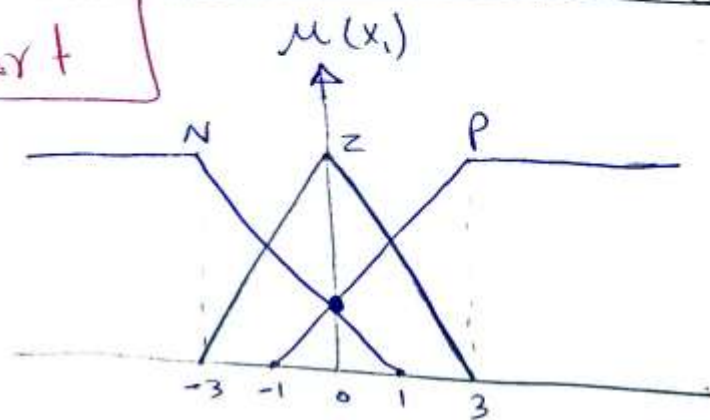
5) Aggregation (OR operation)



له الشكل مثال في استخدام الطريقة

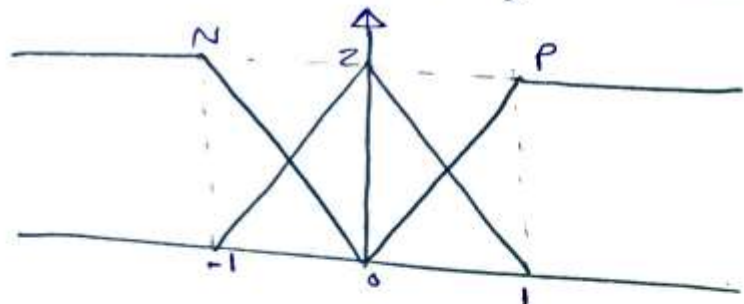
Crisp
u 5 0

Report



استخدم نفس جدول المثال
التي في صفحة 6 .

Find the crisp o/p



$$x_1 = 0.5 \quad (x_2 = 0)$$

